Small-Scale Stand-Alone Hybrid Solar PV and Wind Energy Generation System for EE 452 Lab

Project number: Sddec20-16

Client: Dr. Venkataramana Ajjarapu

Advisors: Dr. Venkataramana Ajjarapu

Members:

Daniel Mendez – Chief Engineer (EE)

Benjamin Holt – Test Engineer (EE)

Samah Shabbo – Meeting Facilitator (EE)

Mohamed Adam – Meeting Scribe (EE)

Conner Makoben – Report Manager (EE)

Team Email: sddec20-16@iastate.edu

Team Website: https://sddec20-16.sd.ece.iastate.edu

Revised: 4/26/2020 Version 3

Executive Summary

Development Standards & Practices Used

- IEEE Guide for Insulation Maintenance of Electric Machines
- IEEE Guide for terrestrial Photovoltaic Power Systems Safety
- IEEE Guide for Selecting, Charging, Testing, and Evaluating Batteries in PV Systems
- IEEE Guide for Array and Battery Sizing in Stand-Alone PV Systems

Summary of Requirements

- Design and develop solar PV and wind regeneration system
- System is safe, compact and easy to use
- Generates energy from solar and wind sources efficiently.
- Capable of generating the maximum energy for varying temperature, irradiance and wind speed.
- Ability to support both AC and DC loads.
- Contain a storage system for excess energy storage.
- Develop lab experiments that enhance the learning opportunities regarding solar and wind generation

Applicable Courses from Iowa State University Curriculum

- EE 201 & EE 230 Electric circuits and systems were used in the circuit design and analysis aspects of the project.
- EE 224 & EE 324 Signals and systems were used in the Simulink simulation aspect of the project.
- EE 452 Electrical machines and power electronics were used to understand electrical loads and their control circuits.

New Skills/Knowledge acquired that was not taught in courses

- Team management - Practicing good communication among ourselves has allowed us to accomplish important tasks
- Project management - We learned how to break down a project from a design and development phase to a project execution plan using effective communication, budgeting and technical skills that each of our group members have obtained
- PV solar cell system - Understand how a PV cell functions and how it plays a role in energy regeneration
- Safety - Solar energy can pose a variety of hazards such as arc flashes and electric shock. Reading and taking precautionary measures allow for safe use of the system

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Introduction

1.1 Acknowledgement

We would like to express our sincere gratitude to our professor of the project (Small-Scale Stand-Alone Hybrid Solar PV and Wind Energy Generation System for EE 452 Lab) for engaging our team in redesigning how we learn about clean energy in a lab setting. Dr. Venkataramana Ajjarapu has given us the space to exchange ideas and insight and have provided us with the mental tools and resources that allow our team to design and develop this project in the first place. We are so grateful for every opportunity we have to be able to walk into your office, as we are able to walk out of it feeling more knowledgeable than the time before.

We would like to express our appreciation to our colleague, Pranav Sharma, who takes time out of his day to sit in our weekly meeting and answer questions for this project. Your assistance and contributions have given the team insight and continue to be the driving force in the work that is necessary to drive this project to completion.

Lastly, we would like to express our appreciation to the previous students for the hard and organized work they have done that made our learning more valuable.

1.2 Problem and Project Statement

The goal of this project is to design and develop a new standalone hybrid renewable energy generation system that will consist of both solar PV and wind energy. The regeneration system will serve as an educational tool for students to learn about clean energy in a safe lab environment.

The current system in the lab is limited to a few capabilities for the following reasons:

1. The standalone system is equipped with solar PV energy as an input and limits the opportunity for students to learn about wind generation
2. The current system is not sized optimally that can be stored in a shelf after use.
3. The system has safety hazards that are potentially dangerous to the user. Some of those include loose wires and connections do not have safety measures such as relays to prevent overcurrent.
4. The system is not equipped with various AC and DC loads to experiment with and limits the education for the student.
5. Lastly, there is only one system that provides limited learning opportunities for everyone to get hands on experience.

After analyzing the current system, there is an area of opportunity for improving the learning about renewable energy generation in a lab environment. A solution is to build a new hybrid standalone system that allows students to gain hands on experience working with solar PV and wind energy in addition to learning how it is used to generate maximum power under changing weather conditions.

We hope to have a functioning standalone system that is safe for the user and enhances the learning environment.

1.3 Operational Environment

The environment of our project is primarily indoors in the Coover 1102 lab with exception to the solar panels located outside of the lab. Since the solar panels will be stationed outside, they will be exposed to various climate changes such as freezing and/or hot temperatures, rain, snow, and hail. These elements are not much of a concern as the panels are constructed to be in outdoor environments and are resilient to these elements. Some occasional cleaning of the panels may need to be done in order to clean any dust or debris off of the panels if they get dirty.

The control system will be located in an indoor lab. This system should be able to withstand use by students at least once a semester and should be able to last many years without maintenance or repairs. The system should also be dry and safe as to not allow for any fire hazards or risk of electric shock to the users.

1.4 Requirements

There are various requirements that need to be met in order to achieve a safe and functional project:

Functional Requirements

- System: System should be compact enough for efficient usability and storage in the lab.
- Generation: Solar Cell should generate the maximum amount of power possible at varying temperatures and solar irradiance.
- Conversion: Conversion circuit should be able to convert from DC to AC power with minimal losses. The system's voltage should be able to increase or decrease in order to match the voltage rating of the load.
- Load: System should be able to power multiple DC and AC loads. System should have an electrical storage system to store excess power.

Environmental Requirements

Availability of Sunlight:

1. The solar panels should be in a centralized area away from walls where the maximum amount of sunlight can be achieved
2. Ideal operating times for the EE 452 lab sessions would be in the springtime during the afternoon hours

Lab Environment:

1. The system should be small enough so that each lab bench would be able to have the system neatly and safely housed for students to have available and to conveniently use
2. A TA should always be present during the lab to ensure that students are using the system properly and will not cause any damage to it, themselves, or others

3. The system should have enough space for the necessary number of batteries and solar panels to provide enough power to each lab bench in the future to avoid situations where there isn't enough power for all lab groups to complete lab

Cost Requirements

Solar Panel	$300	Switches	$30
Wind Turbine	$800	Wires	$40
Arduino	$20	Panel Box	$50
LCD Display	$10	Light Bulb Bank	$100
Relays	$65	Resistor Bank	$100
Multimeter	$150	Total	$1665

Figure 1.4: Cost requirement to build system

Circuit Design Requirement

Hardware

- Array Panel - converts solar energy to electrical energy
- MPPT - Maximum power point tracking allows for the maximum power to be produced.
- Buck/Boost Converter - DC to DC converter that can turn the output voltage to be higher or lower than the input voltage.
- Battery - Stores electrical energy at 12V DC.
- Inverter - converts DC power to AC power.

Software

The software that will be used is Simulink. Simulink is a function in MATLAB that allows the user to simulate the main component of the PV system as well as the voltage, current and the power consumption across the circuit.

1.5 Intended Users and Uses

The end users of this project will be the students in EE 452. They will be using this project as a part of a lab to learn more about solar and wind energy generation and efficiency with both AC and DC loads. The system should be easy for a student to understand and use without complications or any additional assistance aside from what instructions are given within the lab manual. The documentation of the overall project and its design should also be highly detailed so that the ECpE Department would be able to replicate the project in the future or make repairs if needed.

1.6 Assumptions and Limitations

Assumptions

- The system will be replicable so that each lab bench will have the necessary equipment to complete the lab.
- The solar panel arrangement and battery supply will be large enough to be able to generate enough power for each lab bench to be able to effectively complete the lab.
- The system will be compact enough to fit at each lab bench without causing too much clutter and allowing students enough space to work.
- The system will be simple enough for students to understand and use with a clear lab manual guiding them through the lab and how to use the equipment.
- The system will have displays showing the current and voltage being generated within the system for students to easily read.
- The Simulink model will be provided for students to download and experiment with as a part of their lab before using the hardware.

Limitations

- The cost of the solar panels, batteries, and wind turbine add up to a very high cost without the inclusion of the other parts we need which is currently out of our budget unless we can receive additional funds from the department.

- The amount of sunlight on a given day that this lab takes place could affect the experience of the students during the lab in that not enough power may be being generated from the solar panels.

- The location of the solar panels may have shadows cast onto them from the walls of the courtyard.

- Labs taking place during the evening hours may have a varying experience due to the lack of sunlight.

- The efficiency of the wind turbine may not be high due to it being powered manually by a box fan in the lab.

1.7 Expected End Product and Deliverables

The end product that the team will deliver at the end of fall semester 2020 will be a small-scale stand-alone hybrid PV solar and wind energy generation system for EE 452 lab. The system will be used to conduct educational experiments as a part of electrical machines and power electronics lab in Iowa State University. The previous senior design teams delivered a system containing various capacitive, inductive, and resistive loads as AC and DC loads needed in the lab.

Our team will work on redesigning the system by adding more PV solar panels and a wind energy turbine to perform like a hybrid system for maintaining more power supply to increase the experiment stations and power stability during the lab. We will add to the existing system another PV solar panel, wind energy turbine, and two more batteries. The end product deliverables will include modeling and test results showing the performance of the system. In addition, all the instructions and documents to be used in lab manuals. Also, our major deliverable will emphasize the system safety and reliability aspects to give the client ultimate benefit of redesign the existing system.

2. Specifications and Analysis

2.1 Proposed Approach

Since the project has been started by a previous team, we needed to learn and understand what the group has accomplished before it was transitioned to our team. Our team has done the following to better inform ourselves with the status of the project and the path forward towards completing the project.

Safety

Before operating any equipment, we reviewed, as a team, the safety measures we need to take in regard to power systems. The standalone system works with high voltage, therefore, extra precautionary measures were needed before moving any equipment. These standards can be referred to in the “Executive Summary” section “Development Standards & Practices Used.

Research (Solar PV and Wind energy)

Our team began researching how a hybrid energy system functions. More specifically, how solar panels obtain energy and convert it to useful power. The team is working on a presentation that covers our research we have completed to better prepare ourselves on how to design our system.

Transition Documents

Our team has obtained all documents that were left by the previous team. Key documents included weekly reports, design documents, data sheets for equipment and MATLAB files.

Simulink

Our team has simulated various lab experiments that were part of the deliverables for this project to get a better understanding of how the standalone system shall work. This consisted of simulations of PV cells and their functionality.

Hardware Check

Once simulations were complete, we reviewed the system in its current state to understand its functionality. We tested various pieces of equipment where we found areas of improvement.

Identify Project Execution Plan

We developed a detailed project execution plan that will guide us towards completing the project. Please refer to the Appendix for more details.

2.2 Design Analysis

After informing ourselves with the status of the project, we documented our findings that are useful in how we needed to create a path forward for the project.

Transition Documents

Our team has reviewed all documents that were left by the previous team. We noticed some of the specifications of the equipment were left out. Key documentation was missing such as schematics, PFDs, safety procedures, manuals. This is an area of improvement to document all specifications regarding the equipment.

Simulink

Our team has simulated various lab experiments that were part of the deliverables for this project to get a better understanding of how the standalone system shall work. We noticed that some of the lab experiments take very long to identify the concepts that are conveyed to learn. To mitigate this, we will condense the experiments so that they do not take very long but also keep the learning aspect in mind. In addition, the simulation model for studying MPPT was not functioning correctly, so edits were made in order to meet design specifications.

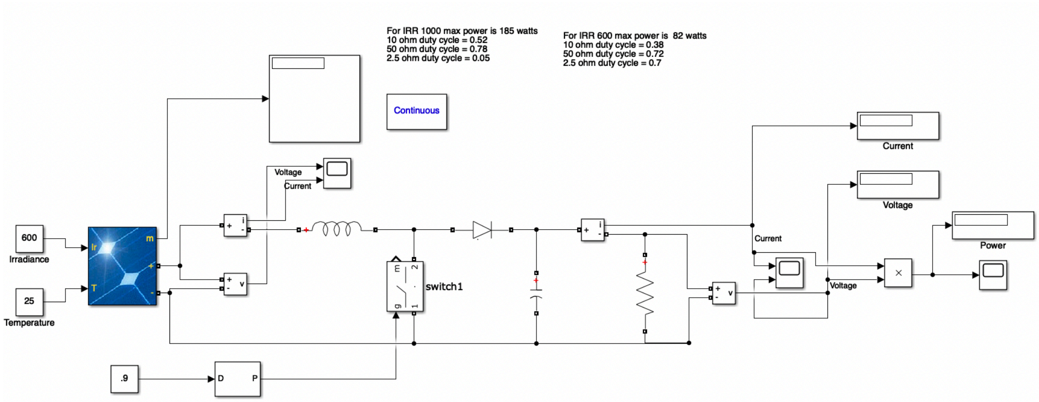

Figure 2.2: Modeling of MPPT behavior without algorithm

<u>Hardware Check</u>

Once simulations were complete, we reviewed the system in its current state to understand its functionality. We tested various pieces of equipment where we found that some of the equipment is not functioning. We found the DC output when switched to MPPT is not functioning. In addition, wiring is not well organized and needs to be fixed.

Figure 2.2.1: MPPT within panel not functioning

<u>Identify Project Execution Plan</u>

We developed a detailed project execution plan that will guide us towards completing a new standalone system. Refer to Appendix for more details.

2.3 Development Process

The team will be using a corporate project management structure that will follow a project from FEL-1 to Project Execution.

2.4 Conceptual Sketch

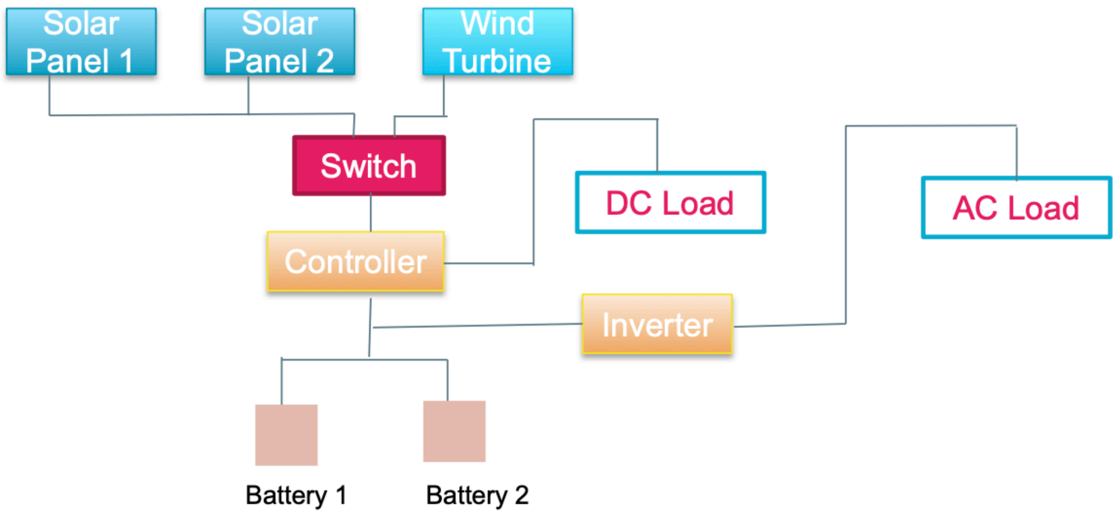

Figure 2.4: Conceptual Sketch of equipment

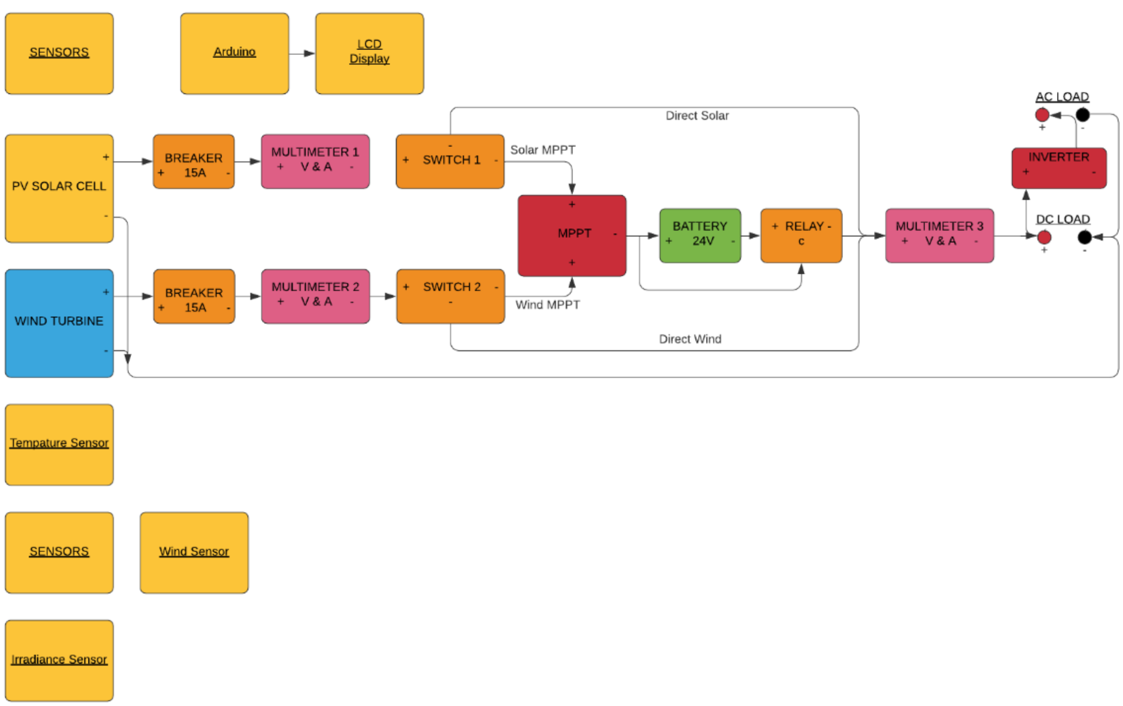

Figure 2.4.1: Detail Design

3. Statement of Work

3.1 Previous Work And Literature

After researching the type of stand-alone system, we would like to design and implement for lab use, we noticed that there is no such system one can buy and equip in a lab setting to study clean energy. However, one can purchase each piece of equipment separately to compose a system according to the specifications the user would like or need. This is a gap our group can fill because we can design, build and operate a solar PV and wind regeneration system that meets lab use standards and safety precautions. This is also an advantage to our group because we can standardize our end-product to market as a system for lab use or as a standalone regeneration system that provides power for equipment on a small scale such as a motor or battery storage to then power a room with a light source. In addition, providing clean energy so that we are not releasing toxic chemicals to our environment that prove to be detrimental.

3.2 Technology Considerations

Data technology:

- Data is stored and displayed using 2 libraries (GFX and TFT LCD).
- A TFT LCD screen displays the irradiance and temperature.
- MPPT Sensors
- Microsoft for creating and editing documents
- Internet and other sources for data collection

Scheduling Technology:

In our project, we use the Gantt chart in Excel for time scheduling. It helps the group to manage, plan and track the project.

Design Technology:

The software that is used in this project for design is Simulink and MATLAB. They allow us to design and simulate the hybrid system. It can simulate the amount of voltage and current across each component of resistor bank and be able to see the power consumption when each load is connected as well as the amount of solar energy needed to power that load.

Communication Technology:

Our group uses university e-mails and group texting for communication.
we use the university website Cybox and google doc for sharing our work and organize the project documents

3.3 Task Decomposition

The four tasks that our project has been divided into are creating and updated lab manual, performing research and cost analysis of the new hardware system, creating a simulation for a wind turbine, and centralizing the documentation of the solar pv circuitry.

The updated lab manual will build upon the work of the last senior design team's lab manual and incorporate new experiments with both Simulink and the hardware that may be more useful and beneficial and also less repetitive.. This lab should also be able to be completed by the EE 452 lab students within the given three hour lab time in the Coover 1102 lab.

Research and cost analysis must be performed on the necessary parts that should be ordered for the new hardware design that is planned to be built in the fall. This cost analysis and parts list should give us a complete estimate of the total cost and the exact parts that should be ordered and ready for construction during the fall semester and to also help aid in the documentation of the overall project for future replication of the design.

The Simulink simulation for the wind turbine should allow for students to input different wind speeds and other variables in order for students to use this in the lab experiments similar to the currently existing solar simulation created by the other design team. This simulation will also aid in the students' understanding of wind generation and help them when also working with the wind generation portion that will be added into the next hardware design.

The centralization of the documents and circuitry of the current and new solar PV system is important to provide for a solid overall understanding of the hardware and how it is working. This will also aid in the design of the new system that will be built based on the certain aspects of the currently existing design. This documentation will also prove to be critical in the future if the ECpE Department chooses to replicate and create more hardware systems for students to use in the lab and each lab bench.

3.4 Possible Risks And Risk Management

Material availability - this is a possible risk due to our planned materials being out of stock or no longer a continued product. The risk can be managed by having multiple options for each component in case such an event occurs. This could change the design constraints of the system if another component is bigger or requires more inputs.

Shipping & Delivery issues - this is a risk because it could hinder the entire hardware build process of the project. If shipping takes up to a month to receive components then adequate time needs to be used in order to receive the components at the start of the fall semester. The possibility of damaged items upon delivery could setback the build process due to new components needed to be reshipped. A way we could manage this risk is working with the vendor to discuss the lead time and find the equipment that meets or time constraints.

Lab Access - With the university moving all classes online and shutting down campus poses a risk to our ability to work on our project in the lab. Since our project cannot be removed from the lab our ability is hindered in the hardware aspect of the project. In order to manage this risk, we are doing everything we can that doesn't involve hands on testing. We are doing this by planning and simulating the project online.

Wind turbine location - Another risk to our project is our wind turbine location due to it being located in the Coover courtyard. Since this turbine spins it can be a risk to others and since the courtyard is open to the public our location needs to be the safest option. This safety risk is being managed by finding a location that would be out of reach to the public. However, there is another risk of the building and grounds department not approving of the location.

3.5 PROJECT PROPOSED MILESTONES AND EVALUATION CRITERIA

There are six major milestones we are targeting for our project as listed below.

Milestone	Mitigation Steps for Completion
Centralizing documentation for Solar PV and Wind Generation System	• Plot plan: drawing that shows where the equipment is located • Loop sheets: drawings that shows all connections of the system • Equipment manuals: reference documentation for troubleshooting • Datasheets: reference documentation for troubleshooting and equipment purchase/comparison • Standard Operating Procedure (SOP): procedure to show how equipment functions and safety precautions when operating equipment
Design and Develop Lab Experiments	• research solar PV and wind generation to understand system • consider safety for users • create lab experiments for Solar PV circuit using panels • create lab experiments for Solar PV circuit using MPPT • create lab experiment for Solar PV using Simulink • create lab experiments for wind circuit • create lab experiment for wind generation using Simulink • learning goals to guide students • solution manual
Wind Turbine Simulation Model	• develop simulation model of wind turbine on Simulink • ensure theory matches with equipment that will be in place
Research, Cost Analysis, and Purchase of equipment	• research equipment that meets our design specifications and safety precautions • develop budget and cash flows chart of purchased equipment and resources • develop bill of materials • work with vendors to ensure equipment can be delivered to campus • purchase equipment within budget to implement for project • retrieve purchased equipment and document what is being used and not used
Execution of Project	• review safety precautions before handling equipment • execute project equipment according to design schedule • ensure all equipment connections are properly connected in the correct places
Safety and Operability Testing	• loop test each connection • isolate each piece of equipment to test functionality • attach meters to analyze voltage, current, and load • make changes according to findings • use lab experiments to see functionality of equipment and compare simulation vs hardware

Figure 3.5: Project milestones

3.6 Project Tracking Procedures

Our group will use a Gant chart to track our progress of each large milestone and each small milestone within those accomplishments. This will prove to organize our project execution in addition to following a set schedule to meet our deadlines.

3.7 Expected Results and Validation

The desired outcome will consist of equipping the EE 452 lab with a new standalone hybrid renewable energy generation system that will be composed of both solar pv and wind energy. The regeneration system will serve as an education tool for students to learn about clean energy in a safe lab environment.

There are three ways we can confirm our solutions work:

1. Ensure the safety our clients, users, and team that maintains the system at all times
2. Our simulation models match the data of the hardware when experimenting
3. The students obtain new knowledge on clean energy (solar PV and wind)

4. Project Timeline, Estimated Resources, and Challenges

4.1 Project Timeline

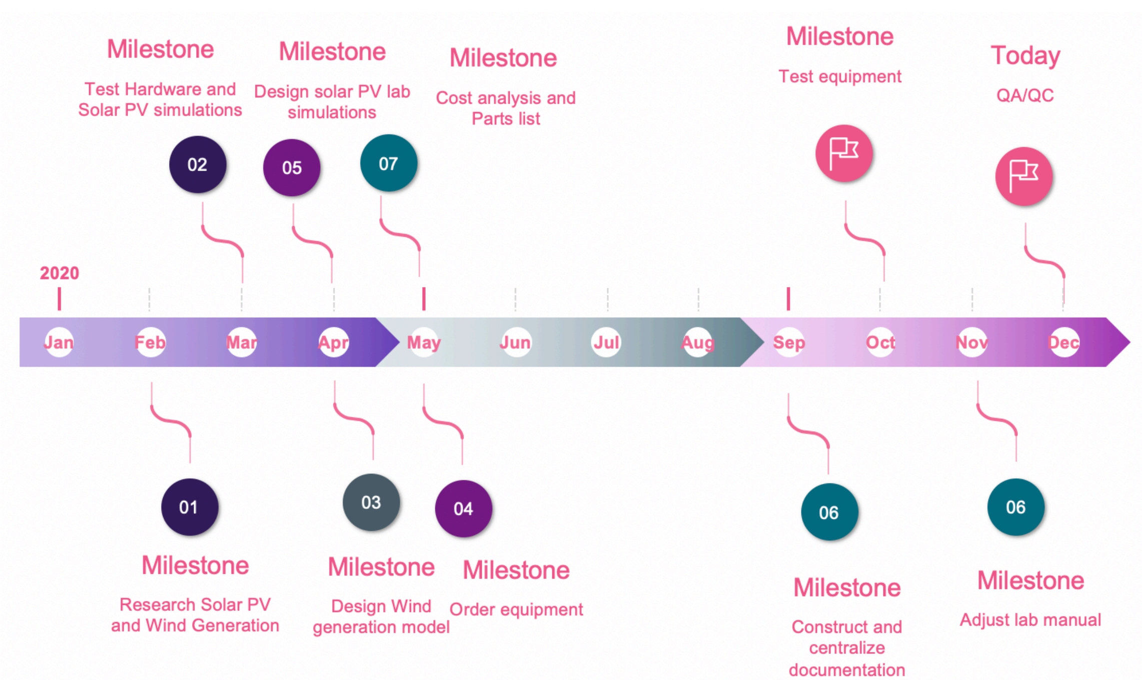

Figure 4.1: Project timeline

The project is planned to be completed within the two-semester time frame by attempting to divide the work up and target which tasks should be completed first before the project can progress. The above Gantt chart is only a tentative schedule consisting of estimated time frames and member allocation. This chart will be subject to change when problems arise or if some tasks prove to require more assistance from other members than anticipated. There may also be new tasks that are realized and should be addressed before progressing along the way; however, by appropriately designating these tasks amongst team members they should be dealt with on time without issue.

The timeline above consists of the estimated time frames for each month that each task will be worked on and brought to or near completion. This timeline has been proposed based on the major tasks that need to be completed. Smaller tasks that need to be done along the way will be distributed to members who should be able to complete them so progress can resume. The first task presented involves researching both solar and wind generation and reviewing the last senior design teams documentation to gain more knowledge on the current system. After this has been completed, new changes, modifications, and additions can be made as necessary through the testing of the system so it would be prepared and ready for the EE 452 lab near the end of the semester. Some additions that need to be made are a Simulink simulation modeling wind generation and also adding a small wind turbine into the new hardware system must be considered and researched. Also mentioned in the schedule is a cost analysis and the construction of a list of parts that should be ordered to build the new system with the addition of wind is necessary. This will help with ordering parts at the end of the semester so that they will be on hand at the beginning of or during next semester for development of the new system. A new lab manual should also be made to include new and updated experiments for the lab that would better benefit students and prove to be more beneficial.

Once the Fall semester begins, the design and construction of the new system can begin. During this design and build process, it will be critical to have the process documented accurately and with many details. This will be important for if the ECpE Department chooses to replicate the system in the future for other lab benches or to make repairs if needed. While building the new system it will also be critical to test it and perform necessary troubleshooting, so that problems will be caught before reaching the end product and discovering that it does not work. Once the system is complete and operational, the new lab manual can then be completed and tested to determine if the system and overall lab will meet the needs of students and the department.

4.2 Feasibility Assessment

Design and implementation of small-scale stand-alone hybrid PV solar and wind energy power system project will serve as educational tool for students to learn about renewable energy in EE 452 lab. Clean energy is an alternating focus of energy to replace the classic types of energy production that have a serious damage to the environment. So, the project will encourage students to study and practice all the aspects of renewable energy from a design perspective. The platform that the project will provide for EE 452 lab consists of several stations to allow sufficient practical opportunities. EE 452 course focuses on electric machines and power electronics that represent the base of power system design and generation. Therefore, the project is so important in areas of redesign and implementing a system that produces more power to the lab by adding a wind turbine and another PV solar panel to the existing design.

As the students used to perform labs in the previous semester by using the existing design, the new design will solve the problems of power supply stability, the relation between the student's numbers and experiment stations number, and the variety of clean energy resources to help students learn more about renewable resources. Power supply stability depends on the weather conditions when the system is not big enough to generate and store enough power during the lab day. Even though students conduct the lab during the mid-day because in Winter the sun irradiance is too low. So, the new design will provide stability to the system in areas of increasing the capacity of energy harvesting and the ability of storing energy in batteries. Also, with a hybrid system the weather conditions will not affect the power supply stability because wind and sun energy will work together. The capabilities of the new design will solve the limitations of existing design and provide enough stations and a safe lab environment for EE 452 students.

The project tasks plan has been achieved as the project timelines. For spring semester, the group focuses on redesigning the system and ordering the new components for the system extension. The redesigning part consists of hardware configuration and modeling in addition to cost analysis. The configuration is in progress and is expected to be delivered at the end of the semester. The modeling of the PV solar is achieved. The simulation of a wind turbine is a real challenge in the project, but the group has been working on it. For wind turbine modeling, most simulations for big scale projects. The modeling of small wind turbine is the project's foreseen challenge, but the group will overcome it during the two semesters of project design.

4.3 Personnel Effort Requirements

Name	Major Milestone	Tasks	% Complete	% End of Fall 2020
Daniel Mendez	Responsible for all engineering and technical disciplines that the project involves	Prepare engineering project tasks	100%	
		schedule the tasks	100%	
		coordinate and monitor project controls	100%	
		ensure project is within standards and regulations	60%	
		QA/QC documents	0%	
		weekly interactions with client to meet needs and requirements of project	100%	
		perform overall quality control of work that includes budget, schedule, plans, personnel and report regularly on project status	80%	
		assign responsibilities and mentor team project	100%	
		communicate effectively with project manager and project participants to provide assistance and technical support	60%	
		review engineering deliverables and initiate appropriate corrective actions	60%	
Benjamin Holt	Centralizing documentation for Solar PV and Wind Generation System	Plot plan: drawing that shows where the equipment is located	see note 1	
		Loop sheets: drawings that shows all connections of the system	see note 1	
		Equipment manuals: reference documentation for troubleshooting	see note 1	
		Datasheets: reference documentation for troubleshooting and equipment purchase/comparison	see note 1	
		Standard Operating Procedure (SOP): procedure to show how equipment functions and safety precautions when operating equipment	see note 1	
Conner Makoben	Design and Develop lab Experiments	research solar PV and wind generation to understand system	100%	
		consider safety for users	60%	
		create lab experiments for Solar PV circuit using panels	60%	
		create lab experiments for Solar PV circuit using MPPT	60%	
		create lab experiment for Solar PV using Simulink	60%	
		create lab experiments for wind circuit	60%	
		create lab experiment for wind generation using SImulink	60%	
		learning goals to guide students	20%	
		solution manual	50%	
Mohamed Adam	Wind Turbine Simulation Model	develop simulation model of wind turbine on Simulink	50%	
		ensure theory matches with equipment that will be in place	50%	
Samah Shabbo	Research, Cost Analysis, and Purchase of equipment	research equipment that meets our design specifications and safety precautions	50%	
		develop budget and cash flows chart of purchased equipment and resources	20%	
		develop bill of materials	20%	
		work with vendors to ensure equipment can be delivered to campus	20%	
		purchase equipment within budget to implement for project	0%	
		retrieve purchased equipment and document what is being used and not used	0%	
All group members	Execution of Project	review safety precautions before handling equipment	0%	
		execute project equipment building according to design schedule	0%	
		ensure all equipment connections are properly connected in the correct places	0%	

note 1: tasks are on hold because it requires the responsible user to work in the lab. Due to the coronavirus outbreak, the responsible person can not access the lab and document the specifications of the equipment

Figure 4.3: Project tracker

4.4 Other Resource Requirements

The main project sources will be in the power electronic drives lab. This lab contains electrical measurements tools, electrical kits, and computer terminals. It is used mainly by students taking EE 452. There are spare components that are available near the system that our team will be able to utilize if necessary

4.5 Financial Requirements

The design team will adhere to one financial resource: The Department of Electrical and Computing Engineering. However, our design team will be responsible for cost analysis and working with The Department of Electrical and Computing Engineering for approval of equipment purchase.

5. Testing and Implementation

5.1 Interface Specifications

The interfacing between software/hardware in our project will be by simulating the operation of our design and testing it before we build the hardware module. We will be using Simulink in MATLAB for that. We will imitate the key characteristics and behaviors of the system. We also will simulate and test modules for all of the core components of our project, for example, we will be capable of simulating and testing the MPPT, solar-system module, and also the wind turbine system.

5.2 Hardware and software

Software:

For the software testing we will use Simulink. Simulink a MATLAB graphical programming environment for modeling, simulating, and analyzing multi domain dynamical systems. Using Simulink, we will be able to test the I-V curve, measure the voltage and current responding to the irradiance and temperature.

Hardware:

For the hardware testing we will use a digital multimeter. The multimeter is an electronic measuring instrument that measures voltage, current, and resistance. It has a numeric display and may also show a graphical bar representing the measured value. Using the digital multimeter, we will be capable of measuring the open circuit voltage, the short circuit current, the operating current of the regulator and any circuit breaker or fuse.

5.3 FUNCTIONAL TESTING

When testing out our system we used these types of functional testing to review our system for any issues.

- **Unit testing** - We did unit testing to see if both our solar,Mppt and wind simulation components worked on their own before implementing them into one complete model.
- **Integration testing** - We tested integrating a Mppt module in simulink on matlab to see if it replicates an actual solar Mppt. We also integrated a wind turbine into simulink to see if a hardware version would work well with our system.
- **System testing** - We tested the system by running it through multiple lab experiments to test out different aspects to see if they matched expected simulation values.
- **Acceptance testing** - We completed acceptance testing by comparing our hardware values to our simulation values to see if they are similar within the acceptable tolerance range.

5.4 NON-FUNCTIONAL TESTING

During the testing of our system we also used the following non-functional testing methods.

- **Performance testing** - We plan on testing the performance of our system by using different load resistances in order to see how much loss occurs in the system. We plan on doing this by comparing the input and output voltages from different loads.
- **Security testing** - We plan on testing our systems security and safety by having someone that is not familiar with our current system try and access it to see any potential flaws.
- **Usability testing** - We used the EE452 ta to give us feedback regarding the usability of our projects lab experiment. We also plan to gain feedback from EE452 students after they complete our lab portion of our project this semester.
- **Compatibility testing** - We plan to test our systems compatibility by trying out multiple different loads that would represent applications in different environments. We could also change out our source components with other models to see if the system functions. However, this wouldn't be feasible due to the high cost of source components.

5.5 PROCESS

Before we began testing equipment on the current standalone system, we needed to understand the specifications and limits of the equipment in order to ensure the safety of all users. Once the team was well informed on the equipment we were operating, we began isolating different areas of the system to test the functionality of the equipment. This involved loop checks, voltage, current and power metering using multimeters. In addition, we simulated the equipment using MATLAB to observe and predict the behavior the equipment to understand the correct operating parameters of the system.

We used the following flow diagram to complete tasks regarding each piece of equipment. This involved various metering of the equipment to ensure that there is no overcurrent or overvoltage flowing through the system to prevent equipment damage or an incident. The result of using this flow diagram insured the safety of all users to prevent any type of electric shock. We note that various areas of equipment was isolated for testing purposes in order to observe the performance of the equipment.

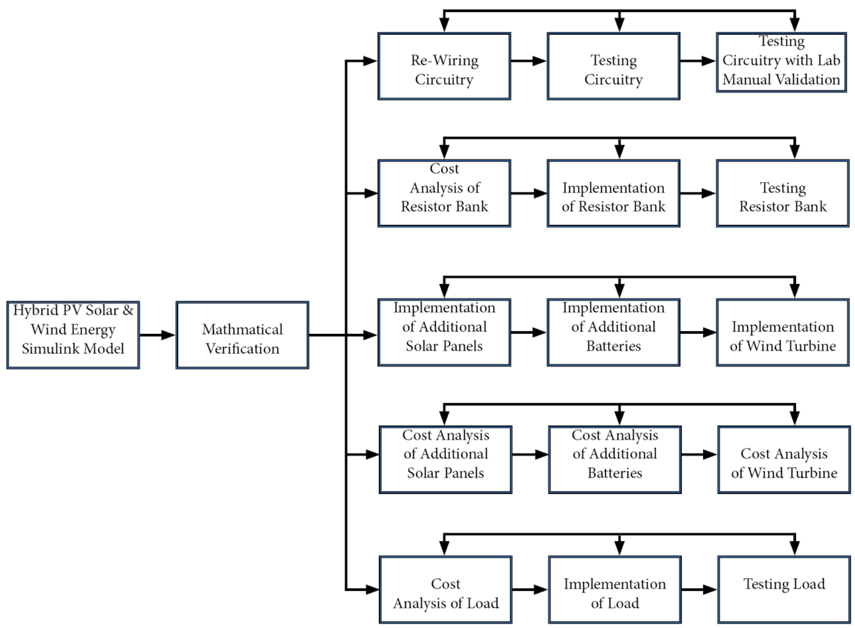

Figure 5.5: Project Flow Chart

5.6 Results

Throughout this semester we have had several accomplishments, but there are also things that still need to be improved and started in the Fall Semester. These accomplishments are listed below as well as progress updates and details

Current Results, Achievements, and Updates:

- Created an updated lab manual for the current Spring Semester
- Successfully completed by the lab groups
- Need to plan to create a new lab manual involving new Simulink simulations and the new hardware that will be built
- Further explored the possibility of adding a wind turbine into both the hardware and software experiments
- The wind turbine Simulink model is still being worked on; however, progress and new ideas have been developed on how to best implement this aspect of the project
- Communicated with the building manager on the possibility of adding a wind turbine into the Coover courtyard
- The turbine cannot be any higher than the walls of the Coover building, but is recommended that the turbine is not located any higher than 10 feet for optimal safety
- Created a new list of materials needed for the new hardware system to be designed and built for next semester
- Gives a general idea of the overall cost of the new project and what materials will need to be ordered
- Took wind measurements in the Coover courtyard to determine whether or not a physical wind turbine would be feasible
- Determined that wind speeds in the courtyard can meet the requirements of the turbines, but the consistency of the wind may be an issue

- Began designing and constructing ideas for the new hardware system as well as creating a more indepth Simulink simulation to better model the hardware and MPPT
- The new Simulink model is being worked on to have a built in logic block to automatically determine the duty cycle input of the DC to DC conversion circuit which will then give the maximum power point at the output based on the input parameters
- Studied the currently existing hardware system to gain a better understanding of how it works and what can be improved upon when building the new system

From these tasks and accomplishments, we were able to gain a better understanding of Simulink as well as PV hybrid systems which we previously had very limited knowledge prior to this project. We were also able to learn more about the current hardware system by studying its documentation and performing experiments with it prior to the transition of online classes.

We do still have much work to do such as finishing the redesign and essentially creating a second prototype of the current system, but now we plan to add a wind turbine into the new system which could bring more challenges next semester if not enough research and planning is done. The updated and more complex Simulink models are also still being tested and built to achieve the desired results for boosting student's learning and allowing them to work with more complex simulations. With these more complex simulations, some more MATLAB programming and research may need to be done in order to fully complete these simulations.

6. Closing Material

6.1 Conclusion

Work that has been completed this semester consists of research into solar and hybrid PV systems, studying and experimenting with the current hardware system and simulations, recreating a new lab manual for this current semester's EE 452 students, and began research and modeling of a wind turbine simulation and considered how one could be implemented into the hardware system.

The goals for this project are to create a safe, effective, and replicable lab for the EE 452 students to use to help them learn about and gain experience with solar, wind, and a hybrid system between the two. To accomplish this we have been working on studying the current system and simulations and learning on how to improve them to create this better learning experience for future students.

This is why it is best to take the time to review the previous design team's materials to search for flaws or improvements that could be made and while doing so we can also gain more knowledge on how we can expand their work to include the wind turbine and be more compact, less complex, and safer. Compared to starting from scratch, this approach is much better because it allows for us to have something to work with and base the new design off of which saves a considerable amount of time.

6.2 References

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Mohammed, Husain. Abu, Tariq. “Modeling and Study of a Standalone PMSG Wind Generation System Using MATLAB/SIMULINK.” Horizon Research Publishing, 2014, http://www.hrpub.org /download/20140902/UJEEE2-17102390.pdf. April 2020.

6.3 Appendices

Deliverable	FEL 1	FEL 2	FEL 3	Detailed Design
Purpose	project ideas, define alternati	evaluate alternatives	define the facility t	Design for project ex
Drawings				
Process Flowsheet				
P&ID drawing				
Key Plan/Site Plan				
General Arrangements				
Details				
Electrical Schematics				
Cable Schedule				
Instrument Loop Drawings				
Piping Line List				
Vendor Information/Drawings				
Shop Drawings				
Other				
Design Calculations				
Scope of Work/Report				
Equipment List				
Instrument List				
Process Hazards Review				
Soils Investigation Report				
Equipment Quotations				
Lifting Device Certification				
Specifications				
Cost Estimate				
Approvals				
TSSA				
ESA				
Building Permit				
Excavation Permit				
Buried Services Locates				
Insurance Underwriter				
Min if Natural Resources				
Project				
Engineering(% of Total Eng)				
Approx Eng Hours				
Estimate Method				
Estimate accuracy				

Figure 6.3: QA/QC Documentation